10/580128
IAP9 Rec'd PCT/PTO 19 MAY 2006

Method for controlling a drive motor of a positive displacement vacuum pump

BACKGROUND

The invention relates to a method for controlling a drive motor of a positive displacement vacuum pump, and to a positive displacement vacuum pump comprising a drive motor control.

Positive displacement vacuum pumps are, for example, membrane pumps, rotary vane pumps, piston pumps or Roots pumps, and are frequently used as fore vacuum pumps in combination with a high vacuum pump. A special feature of these positive displacement vacuum pumps is that the final pressure attainable by said pumps, i.e. the fore vacuum pressure, is speed-dependent to a high extent, wherein the speed must be high at high inlet pressures, and must be low at low inlet pressures for attaining an optimum suction capacity. This can be explained by the fact that at low inlet pressures filling of the suction space takes place at a relatively slow rate due to the small difference between inlet pressure and suction pressure in the working chamber. This results in a poor filling level of the positive displacement vacuum pump at low inlet pressures, which filling level can only be improved by extending the opening times of the inlet valve, i.e. a speed reduction.

From DE 198 16 241 C1 a positive displacement vacuum pump is known which is operated, in dependence on an inlet pressure value, at two different speeds, namely at a high speed for evacuation purposes, and at a low speed for reaching the lowest final pressure possible. Relatively much time is required between the beginning of the pumping process and reaching of the final pressure.

SUMMARY

It is an object of the invention to provide a method and a positive displacement vacuum pump with the aid of which the final pressure can be more rapidly reached.

According to one aspect, a method is provided for controlling a drive motor of a positive displacement vacuum pump comprises the method steps of storing a pressure-speed curve, determining the inlet pressure value, determining the speed value from the curve, and operating the drive motor at the determined speed value.

First, a curve is stored in which a single constant upper speed value n_1 is associated with inlet pressure values p larger than or equal to an upper limit pressure p_1, and which comprises an alteration range for inlet pressure values p smaller than the upper limit pressure p_1, wherein in the alteration range different speed values n_v are associated with the inlet pressure values p.

During operation of the drive motor the inlet pressure value p is permanently determined, the associated speed n is determined from the inlet pressure value p of the curve, and the drive motor is operated at the determined speed n. While at high inlet pressure values p above the upper limit value p_1 the drive motor is operated at a maximum constant speed n_1, a corresponding speed value n_v is approximately continuously associated for speeds above the upper limit value p_1 in dependence on the inlet pressure value p. In this manner, the effective suction capacity of the positive displacement pump can be kept at the highest level possible for each inlet pressure value. Thus, the time between beginning of evacuation and reaching of the final pressure is decreased. By adapting the speed to the inlet pressure value, the required drive energy and, due to the lower average speed level, the wear are reduced. Thereby, the maintenance and operating costs are reduced, and thus the efficiency of the positive displacement vacuum pump is improved.

Preferably, the curve comprises a lower range for inlet pressure values p smaller than or equal to a lower limit pressure p_2, wherein a single constant lower speed value n_2 is associated with the lower range, and the alteration range is limited to inlet pressure values p larger than the lower limit pressure range p_2. The curve thus comprises both an upper pressure range of constant

speed and a lower pressure range of constant speed, as well as an alteration range of non-constant speed between said two ranges. Such a curve is, for example, necessary and useful for fore vacuum pumps which need a given minimum speed for pumping action since below the minimum speed no pumping capacity can be attained, in particular due to backflow losses. This applies, for example, to oil-sealed rotary vane pumps. Thus it is ensured that the positive displacement vacuum pump is always operated above a speed at which the pumping function is still guaranteed even at very low inlet pressures.

According to a further aspect, the curve comprises, instead of an upper range, a lower range for inlet pressure values p smaller than or equal to a lower limit pressure p_2, wherein a single constant lower speed n_2 is associated with the lower range.

Preferably, in the alteration range decreasing speeds n_v are associated with decreasing inlet pressure values p, i.e. low speed values n_v are associated with low inlet pressure values p.

Preferably, the upper limit pressure p_1 ranges between 20 mbar and 1 mbar, and the lower pressure p_2 ranges between 1.0 mbar and 0.005 mbar, wherein the upper limit pressure p_1 is larger than the lower limit pressure p_2.

According to a preferred aspect, the upper constant speed value n_1 ranges between 2,200 and 1,000 rpm, and the lower constant speed value n_2 ranges between 300 and 1,300 rpm, wherein the upper constant speed value n_1 is larger than the lower constant speed value n_2.

Preferably, the positive displacement pump is a fore vacuum pump arranged upstream of a high vacuum pump, and the inlet pressure value p is the suction-side pressure of the high vacuum pump. The inlet pressure value p thus is the pressure in the recipient evacuated by the high vacuum pump. Alterna-

tively, the inlet pressure value p may also be the fore vacuum pressure immediately before the inlet of the fore vacuum pump.

According to a preferred aspect, the inlet pressure-speed curve is saved in a characteristic diagram storage. In the characteristic diagram storage, a corresponding speed n is associated with each inlet pressure value p.

Preferably, the drive motor is an asynchronous motor driven by a correspondingly driven frequency converter. However, the drive motor may also be configured as a synchronous motor.

The positive displacement vacuum pump comprises a drive motor, an inlet pressure sensor and a drive motor control which controls the speed n of the drive motor in dependence on the inlet pressure value p determined by the inlet pressure sensor. Further, the drive motor control comprises a storage for storing a curve that indicates a respective speed n of the drive motor for the inlet pressure values p of the inlet pressure sensor, wherein the curve comprises two ranges: the first range is an upper range for inlet pressure values p larger than or equal to an upper limit pressure p_1, with a single constant upper speed value n_1 being associated with said first range. The second range is an alteration range for inlet pressure values p smaller than the upper limit pressure p_1, wherein in the alteration range different speed values n_v are associated with the inlet pressure values p.

Preferably, the drive motor control comprises a processor which has connected therewith the inlet pressure sensor and evaluates the signals from the inlet pressure sensor. The evaluated inlet pressure sensor signals can be supplied to a pressure indicator associated with the positive displacement vacuum pump. The inlet pressure sensor signals are thus not only evaluated by the drive motor control with regard to controlling the drive motor, but also converted into an indication format, and finally supplied to an indicator associated with the vacuum pump. Thus a separate evaluating and indicating device for indicating the inlet pressure is not required.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment of the invention will now be described in greater detail with reference to the figures in which:

Fig. 1 shows a schematic representation of a pump assembly comprising a positive displacement vacuum pump according to the invention configured as a fore vacuum pump, and a high vacuum pump, and

Fig. 2 shows an inlet pressure-speed curve according to which the speed of the drive motor of the positive displacement vacuum pump is controlled.

DETAILED DESCRIPTION

Fig. 1 schematically shows a pump assembly 10 for generating a high vacuum in a recipient 12. For the purpose of generating the high vacuum in the recipient 12, two pumps are arranged in series, namely a high vacuum pump 14, for example a turbomolecular pump, and a positive displacement vacuum pump 16 configured as a fore vacuum pump, for example a membrane, piston or rotary vane pump.

The positive displacement vacuum pump 16 essentially comprises a pump device 18 having a displacement body arranged in a pumping chamber, a drive motor 20 for driving the pump device 18, and a drive motor control 22 for controlling and supplying energy to the drive motor 20. The drive motor 20 is configured as a synchronous motor.

Further, the pump assembly 10 comprises two inlet pressure sensors 24,26, wherein one of the inlet pressure sensors 24 determines the fore vacuum pressure immediately at the inlet of the positive displacement vacuum pump 16, and the other inlet pressure sensor 26 determines the high vacuum pressure in the recipient 12. Both inlet pressure sensors 24,26 are connected with a processor 28 of the drive motor control 22, said processor 28 being con-

tinuously supplied with inlet pressure values p by the inlet pressure sensors 24, 26. The drive motor control 22 further comprises a frequency converter 30 driven by the processor 28, and is connected with the drive motor 20. Further, the inlet pressure sensor 24 associated with the positive displacement vacuum pump 16 may be integrated in the positive displacement vacuum pump 16.

The processor 28 comprises a characteristic diagram storage for saving a curve 32 in which a respective speed n of the drive motor 20 is associated with inlet pressure values p.

The curve 32 comprises an upper range 34 extending from the atmospheric pressure of 1,013 mbar to an upper limit pressure p_1 of 10 mbar. A single constant upper speed value n_1 is associated with the upper range 34 of the curve 32. Between the upper limit pressure p_1 and a lower limit pressure p_2 of approximately 0.01 mbar, the curve 32 comprises an alteration range 36 in which various speed values n_v are associated with the inlet pressure values p. In the alteration range 36 of the curve 32 decreasing speeds n_v are associated with decreasing inlet pressure values p. In the alteration range 36 a different speed value n_v is associated with each inlet pressure value p. The curve 32 further comprises a lower range 38 for inlet pressure values p smaller than or equal to the lower limit pressure p_2. In the lower range 38 of the curve 32 a single speed value n_2 is associated with all inlet pressure values p.

In a pump device 18 configured as a piston pump, the upper speed value n_1 is approximately 1,800 rpm, and the lower speed value n_2 is 500 rpm. In a pump device 18 configured as an oil-sealed rotary vane pump, the upper speed value n_1 is, for example, 2,100 rpm, and the lower speed value n_2 is 1,000 rpm.

The high vacuum pressure serves as the inlet pressure value p which is supplied by the inlet pressure sensor 26 arranged at the recipient 12 and on the suction side of the high vacuum pump 14. Alternatively, the fore vacuum

pressure of the inlet pressure sensor 24 may be used for determining the inlet pressure values p.

The shape of the curve 32, the limit pressures p_1 and p_2, and the upper and lower speed values n_1 and n_2 are determined in test series for establishing for each inlet pressure value p a drive motor 20 speed at which a maximum effective suction capacity of the positive displacement pump 16 is attained. The determined curve is subsequently stored in the characteristic diagram storage of the processor 28. During operation of the pump assembly 10, the drive motor control 22 determines, from the curve 32 saved in the characteristic diagram storage, the speed n of the drive motor 20 in dependence on the high vacuum inlet pressure value p. The determined speed value n is fed to the frequency converter 30 which generates corresponding rotating fields in the stator coils of the drive motor 20 configured as asynchronous or synchronous motor, and operates the motor at the determined speed. In this manner, the positive displacement pump 16 can always be operated at the maximum effective suction capacity.

The processor 28 of the drive motor control 22 further carries out evaluation and conversion of the signals from the inlet pressure sensor 24 into an indication format. The inlet pressures converted into the indication format are supplied to an indicating device arranged at the positive displacement vacuum pump 16, for example at the housing of the drive motor control 22. The indicating device may further be used for speed indication.

The invention has been described with reference to the preferred embodiments. Modifications and alterations may occur to others upon reading and understanding the preceding detailed description. It is intended that the invention be constructed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.